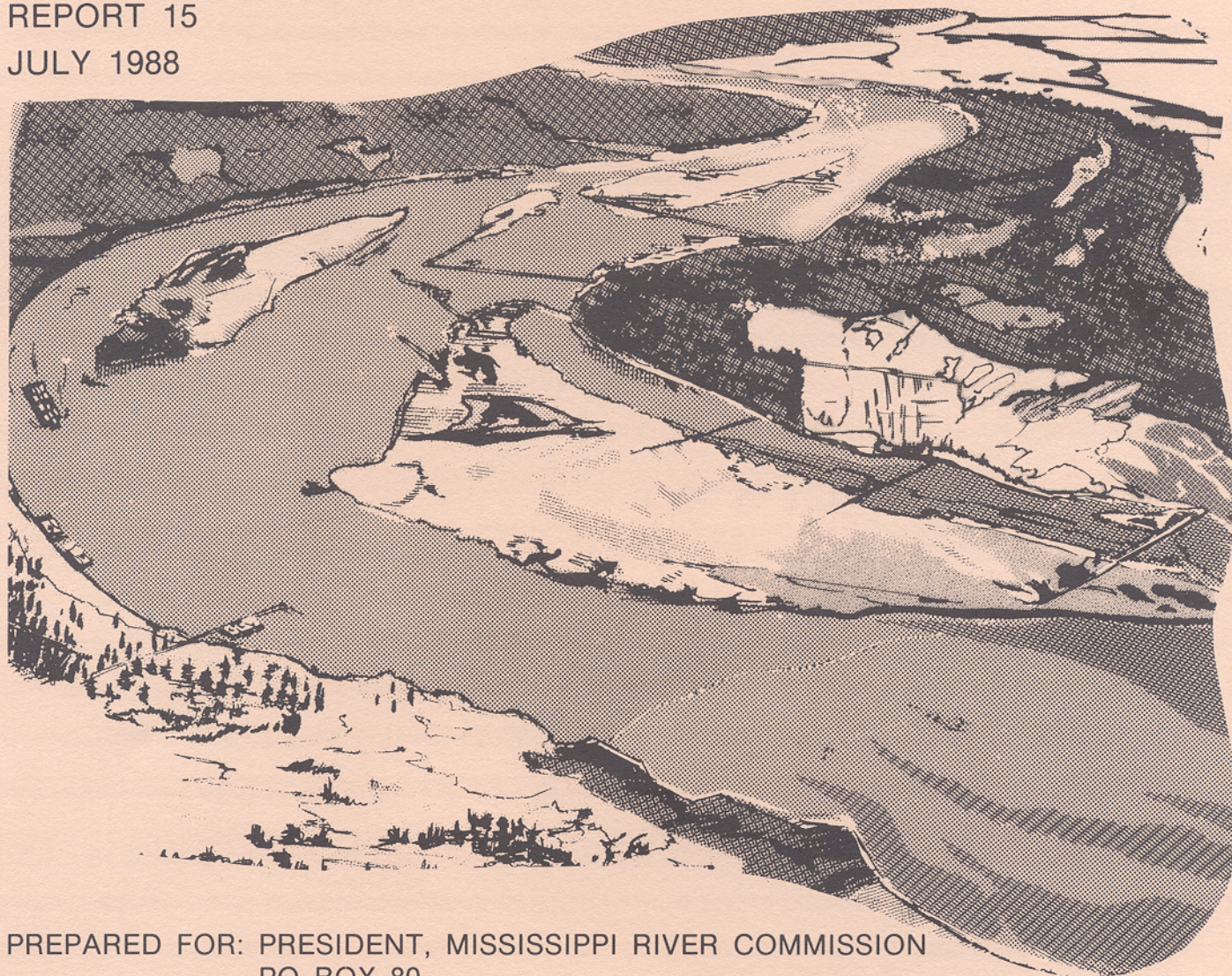




**US Army Corps
of Engineers**
Mississippi River
Commission

VEGETATION DEVELOPMENT ON REVETMENTS ALONG THE LOWER MISSISSIPPI RIVER

LOWER MISSISSIPPI RIVER ENVIRONMENTAL PROGRAM
REPORT 15
JULY 1988



PREPARED FOR: PRESIDENT, MISSISSIPPI RIVER COMMISSION
PO BOX 80
VICKSBURG, MISSISSIPPI 39180-0080

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19. ABSTRACT (Continue on reverse if necessary and identify by block number) Nearly 900 miles of bank protection works (revetments) are in place along the Lower Mississippi River. These structures are composed of a variety of materials and support various degrees of vegetation cover. Plant establishment on revetted banks has implications for both bank stability and wildlife habitat quality; therefore, a study was initiated to investigate the relationship between vegetation development and revetment features and materials. Field sampling at 25 sites indicated that vegetation development was more pronounced on upper than lower banks and on sites protected from direct impacts of high-velocity flows. Loose rock paving (riprap), which is typically employed on upper banks, generally supported the most vegetation. Plants were frequently found growing between the blocks of articulated concrete mat revetments. Asphalt paving had high herbaceous cover, but tree establishment was limited. In general, only two species of trees (<u>Salix nigra</u> and <u>Salix interior</u>) commonly occurred on the lower half of revetted banks. (Continued)					
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Upper banks and the top bank zone supported a more diverse tree species assemblage. Vines were a major component of revetment plant communities on the upper bank. Ground cover vegetation was more abundant in higher bank zones, but many annual species were able to colonize the lower bank where sediment was deposited as the river receded.

PREFACE

The Lower Mississippi River Environmental Program (LMREP) is a comprehensive investigation of the Lower Mississippi River and its leveed floodplain being conducted by the Mississippi River Commission (MRC), US Army Corps of Engineers. The objectives of the LMREP are to obtain environmental inventory data on the project area and to develop environmental design considerations for navigation and flood control features of the Mississippi River and Tributaries Project (MR&T).

This report was prepared as part of the Environmental Inventory Task of the LMREP. Dr. Charles Klimas, Environmental Laboratory (EL), US Army Engineer Waterways Experiment Station (WES), was the principal investigator and participated in designing the study and preparing the final report.

Dr. James W. Webb, Texas A&M University at Galveston, performed the field work and data analyses and prepared the basic report. Dr. Daniel K. Evans, Marshall University, Huntington, West Virginia, and Mr. Harvey L. Jones, EL, also participated in data collection. Ms. Virginia Sotler, EL, assisted with data base design and other computer programming.

This research was managed by the Planning Division, Environmental Analysis Branch, of the MRC and was sponsored by the Engineering Division, MRC. Mr. D. E. Lawhun was Chief, Planning Division; Mr. Hugh T. Holland was Chief, Environmental Analysis Branch; and Mr. Fred H. Bayley III was Chief, Engineering Division, during the conduct of this study. Mr. Stephen P. Cobb, MRC, was the program manager for the LMREP. The investigation was conducted under the direction of the President of the Mississippi River Commission, MG Thomas A. Sands, CE.

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LOWER MISSISSIPPI RIVER ENVIRONMENTAL PROGRAM
VEGETATION DEVELOPMENT ON REVETMENTS ALONG THE
LOWER MISSISSIPPI RIVER

PART I: INTRODUCTION

Background

MR&T Project

1. The Mississippi River and Tributaries (MR&T) Project is a comprehensive flood control and navigation plan for the Lower Mississippi River and tributary streams. The MR&T was authorized under the Flood Control Act of 1928 and is the responsibility of the Mississippi River Commission (MRC). The project consists primarily of a system of levees, channel improvement works, and floodways.

Environmental Program (LMREP)

2. The LMREP is a 7-year inventory and research program initiated in 1981 under the direction of the MRC. The objectives of the LMREP are to assemble baseline data on environmental resources of the leveed floodplain of the lower river and to develop environmental design considerations for main-line levees, revetments, and dike systems for the MR&T project. The LMREP is made up of five work units: (a) levee borrow pit investigations; (b) dike system investigations; (c) revetment investigations; (d) environmental inventories, including development of a Computerized Environmental Resources Data System (CERDS); and (e) development of environmental design considerations.

Revetment Vegetation Study

3. The MR&T Project includes authorization for 968.16 miles of revetment on the Lower Mississippi River, of which 875.0 miles had been completed as of 1 January 1987. Revetments arrest lateral movement of bank lines and stabilize the alignment of the channel (Tuttle and Pinner 1982). They are constructed by grading and armoring the bank, particularly along bendways subject to direct attack by currents. Although various construction materials have been used over the years, most revetments consist of articulated concrete

mattress (ACM) on the subaqueous bank and either broken stone (riprap) or asphalt paving on the upper bank. Asphalt is no longer used and is gradually being replaced by stone on older revetments during routine maintenance.

4. Periodic repairs and changes in materials and methods over the years have produced a combination of treatments on many revetted banks. These treatments are often overlapping and of various ages. Some sites are heavily vegetated; others show little plant colonization, even after many years of being in place. The research reported herein was designed to detect the major factors influencing plant establishment on revetted banks.

PART II: METHODS

5. Twenty-five sites were selected for sampling on the lower river in August 1985 (Table 1). A stratified sampling design was used to assure sample coverage of the major variations in revetment types, bank configuration, and degree of vegetation development, all of which were adequately represented in the reach between River Miles 27.5 and 574.0. In all cases, selection of specific sampling sites at a revetment complex was accomplished using systematic field procedures.

6. Each revetment sampled was categorized with respect to its orientation relative to river channel alignment (Fig. 1). In bendways, revetments are generally placed on the concave bank. Samples collected at the apex of the bend were given the site designation "concave," and samples collected upstream and downstream of the apex were designated as "upper bend" and "lower bend," respectively. Occasionally, revetments are constructed on the convex side of a bendway, and samples from the apex of these sites are identified as "convex." Sample sites were also established on revetments constructed on straight reaches (straight) and where revetted bank sections were somewhat recessed relative to the adjacent banks (eddies). Sample site locations (river mile) and construction dates were recorded as indicated by the MRC (1985). Construction dates may not reflect subsequent reinforcement or maintenance work.

7. At each selected sampling site, three transects were established at 50-m intervals along the bank, oriented perpendicular to the river. The 50-m interval was reduced by increments if the sampling site was too small to contain the standard transect array. Each transect was subdivided into six segments reflecting relative elevation above the water surface (low, mid-low, mid, mid-high, high, and immediately above the revetment (top bank)). These segments were divided into plots 1 m wide and 2 m long. The number of plots varied between transects and elevational segments depending on the length and slope of the revetment face. For top bank plots the revetment type was designated based on the greatest number of samples in a particular revetment type in that transect. Top bank plots were excluded from most statistical comparisons because they were not located on the revetment structure. There were 144 plots sampled immediately above revetments.

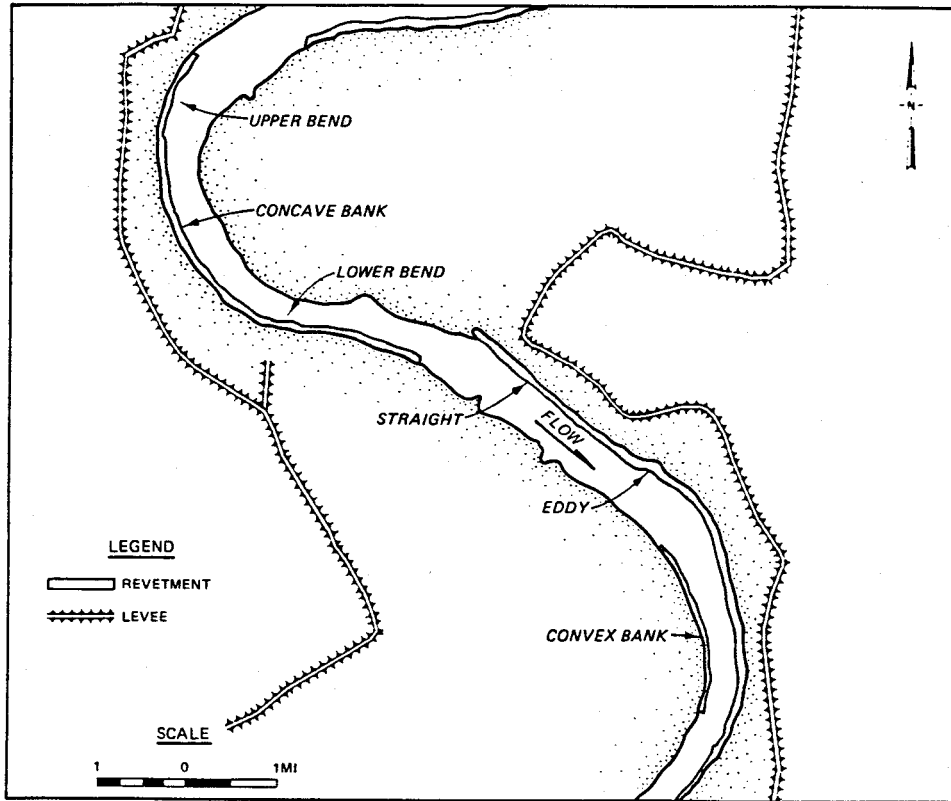


Figure 1. Typical revetment placement on the Lower Mississippi River, with bank line orientation designations indicated

8. Within each plot, the following data were recorded:
 - a. Total ground cover (percent).
 - b. Ground cover (percent) by species.
 - c. Vine density (number of stems) by species.
 - d. Tree seedling density (number of stems) by species.
 - e. Tree and shrub density (number of stems) by species.
 - f. Overstory cover (percent) by species (for woody stems >1.4 m tall).
 - g. Slope (percent).
 - h. Woody debris accumulation (percent cover).
 - i. Predominant soil texture.
 - j. Sediment accumulation (sediments deeper than 40 cm recorded as 40 cm).
 - k. Substrate type on the revetted bank.
 - (1) Riprap (RR).
 - (2) Articulated concrete mat (CM).
 - (3) Asphalt (AS).

- (4) Riprap over asphalt (RA).
- (5) Riprap over articulated concrete mat (RM).
- (6) Asphalt over articulated concrete mat (AC).
- (7) Articulated concrete mat over asphalt (CA).
- (8) Unknown (sediment accumulation prevented determination) (UN).

PART III: RESULTS

9. The most common types of revetted bank substrates (Table 2) were rip-rap (330 plots), articulated concrete mat (226), and asphalt (191). Various combinations of the above types were encountered in 115 plots. The type of substrate was recorded as unknown 67 times because sediment accumulation precluded accurate determination. The type of substrate varied with riverbank elevation zones (Table 2) and reflected standard construction practices. Rip-rap most frequently occurred on the bank in zones above articulated concrete mat revetment (i.e., middle, mid-high, and high zones). Articulated concrete mat was the most frequently encountered substrate type on the lower slopes of revetted banks. This material was infrequently found on the higher portions of the river bank (mid-high to high) because the mat was laid up to the water's edge at the time of construction, which was usually during low river stage periods.

10. Average sediment depth was not significantly different across relative elevation zones except for the top bank zone, which had consistently deeper sediments (Table 3). The correlation (top bank zone excluded) of sediment depth with ground cover ($R = -0.02$) and overstory cover ($R = -0.10$) did not indicate that depth of sediment accumulation was critical to or enhanced plant colonization (Table 4).

11. The most apparent trend noted in the sample data was that ground cover, overstory cover, and debris cover increased with increasing riverbank elevation zones, regardless of the type of substrate present (Table 3). The increase in ground cover was particularly striking. Statistically significant ($p < 0.05$) differences in ground cover occurred between each zone, except between the low and mid-low zones. Ground cover in the top bank zone (where sediment was deep, terrain was flat, and inundation was only occasional) was much greater than the ground cover on the revetment. Mean overstory cover was significantly higher in the high and overbank zones than in any lower bank samples.

12. Statistically significant differences ($p < 0.05$) among substrates occurred (combined elevations) for ground cover, overstory cover, debris cover, sediment depth, and slope (Table 5). Ground cover and overstory cover varied significantly among elevation zones from mid-low to high elevations (overstory cover was not different at the mid-high zone). In the high

elevation zone ground cover was greatest on substrates that included asphalt (asphalt, asphalt over articulated concrete mat, riprap over asphalt) followed by riprap and articulated concrete mat. In contrast to ground cover, overstory cover was highest on the articulated concrete mat, riprap and riprap over asphalt substrate types. Ground cover was low where the substrate was overlain by deep sediments regardless of the elevation. Plant colonization of deep sediments over artificial substrates appeared to be primarily by rafted seeds of annual plants deposited by receding flood waters.

13. There were 27 tree, shrub, or vine species recorded in the overstory samples (Table 6). Salix nigra,* Platanus occidentalis, and Salix interior were the dominant canopy species. Salix nigra and S. interior were the only common overstory species in the middle elevation zone and the only overstory species in the low and mid-low zones. Platanus occidentalis and Amorpha fruticosa, a shrub, were the most common woody plants of the mid-high and high elevations. Only three other tree and shrublike species, Fraxinus pennsylvanica, Populus deltoides and Sesbania exaltata occurred with any regularity on the revetted banks (top bank zone excluded) (Table 7). Of the 14 species of trees that occurred on revetments (top bank excluded) S. interior was the only one that grew in the lowest zone (Table 7). Salix nigra and S. interior were the only tree species growing in the low and mid-low zones. All S. interior trees growing in the three lowest zones (low, mid-low, and middle zones) were less than 10 cm in diameter (Table 8). However, 8 of the 14 S. nigra trees that occurred in the 3 lowest zones ranged from 10-25 cm in diameter. Seven tree species occurred in the middle and 8 in the mid-high elevation zones; 12 species occurred in the high zone and 13 species occurred immediately above the revetments (Table 7 and Table 8). Amorpha fruticosa and S. interior were numerous in the mid-high zone. Amorpha fruticosa and small (<5 cm dbh) P. occidentalis were common in the high and top bank zones while S. interior was uncommon on these sites. Salix nigra and P. occidentalis were the only trees that exceeded 15 cm in diameter on the revetments.

14. Salix interior, S. nigra, and P. occidentalis occurred primarily in riprap (Table 7). Amorpha fruticosa (a shrub) grew well on asphalt, riprap, or articulated concrete mat substrates. Trees established on articulated

* Common names of plant species mentioned in this report are provided in Appendix A.

concrete mats occurred in the gaps between the concrete slabs. No trees were found where deep sediments had accumulated, except in the topbank zone.

15. The species composition of woody plant seedlings (Table 9) tended to reflect overstory composition. Salix nigra seedlings occurred most frequently and at the highest densities. Salix interior had the second highest frequency of occurrence, but P. deltoides seedlings were second in total abundance. Amorpha fruticosa also had relatively high numbers of seedlings. The only other species that occurred in large numbers was Celtis laevigata. Except for S. interior and S. nigra, most seedlings occurred above the middle elevation zone.

16. Twelve species of vines reached the overstory layer (above 1.4 m) in the sampled plots (Table 10). Most vines grew at or above the middle elevation zones. Ampelopsis arborea and Campsis radicans occurred most frequently and at the highest densities. Strophostyles helvola was also common and abundant. Vitis riparia and Brunnichia cirrhosa were relatively uncommon but were locally abundant where they occurred. Many of these vine species contributed heavily to ground cover.

17. A wide variety of species was encountered in the ground cover category (Table 11). To facilitate discussion, they were classified as "very important" if mean cover for all plots exceeded 2.0 percent, "important" if mean cover was between 0.7 and 1.9 percent, and "common" if mean cover was between 0.2 and 0.69 percent. These arbitrary divisions reflect natural breaking points in the data.

18. Seventeen plant species, including vines, annual and perennial forbs and grasses, and small trees and shrubs, were very important ground cover components (Table 11). Three vine species, C. radicans, S. helvola and Ipomoea pandurata, were particularly common and abundant, with the number of plots of occurrence exceeding 35 and cover averaging about 50 percent within those plots. Four other vine species, Rubus trivialis, A. arborea, B. cirrhosa, and Rhus radicans, were also very important.

19. Most ground cover species tended to increase in percent coverage and frequency of occurrence with increasing bank elevation. Exceptions were Amaranthus tamariscinus, S. interior, Eclipta alba, Molugo verticillata, Fimbristylis vahlii, and Eragrostis hypnoides. These species tended to occur on deposits of sediments at low elevations.

20. Percent cover and frequency of ground cover plants categorized as "very important" (Table 12) indicated that in low, mid-low and middle elevation zones, riprap and articulated concrete mat substrates were more heavily colonized than other substrate types. Asphalt substrates were generally sparsely colonized downslope of the middle elevation zone. Where riprap or articulated concrete mat was placed over asphalt (RA and CA), colonization was slightly greater. In the mid-high elevation zone, average percent ground cover was similar for riprap, articulated concrete mat, and articulated concrete mat over asphalt. Riprap and asphalt substrates were more frequently colonized than other substrate types. Cyperus esculentus was a frequent colonizer on asphalt but generally contributed little to overall cover. At the high elevation, riprap, riprap over asphalt, and asphalt had higher plant cover and frequency than articulated concrete mat. Some very important species, particularly vines, were absent from articulated concrete mat substrate in this zone.

21. Statistically significant differences among sites occurred by river mile (Table 13) and age (Table 14) in ground cover, canopy cover, debris cover, sediment depth, and percent slope, but no particular pattern of variation was apparent other than a tendency for debris and sediment to accumulate on the gentler slopes downstream of New Orleans. Species composition was also somewhat different downstream of New Orleans. Otherwise, there were no apparent latitudinal or age gradients in any of these variables. Correlation coefficients of river mile (latitude) and age with ground cover, canopy cover, debris cover, and sediment depth were very low (Table 4).

22. An important factor in plant establishment may be bank line orientation (Table 15). For combined elevations, ground cover was greater on upper bend sites than on other sites. The trend was evident at all elevations except the low elevation where no colonization occurred. Overstory cover for combined elevations was significantly greater at eddy sites. The high elevation zone on bendway apexes also had high canopy cover.

23. At all elevations (excluding the top bank zone) the greatest sediment accumulation was in the apex of bends, followed by the upper bend (Table 15). The tendency for sediment deposition to occur on concave bends was in contrast to the typical pattern of erosion on such sites and deposition on convex (point bar) bends. This suggests that the observed accumulation was probably deposited by falling river stages and was an ephemeral condition. Debris

accumulation was generally low in bends. The lower section of bends tended to be more steeply sloped than other revetted areas.

PART IV: DISCUSSION

24. A variety of environmental factors apparently influenced plant colonization and community development on revetments. Plant species composition and cover were strongly related to relative elevation on the bank. Perennial herbs, vines, and trees, except for Salix species, generally occupied the middle or higher zones. Scouring currents and sediment deposition apparently were major factors in preventing establishment of plants, particularly perennials, at lower elevations. However, ephemeral populations of annual forbs and grasses, and tree seedlings were often present on low elevation sediment deposits. Composition and cover on such sites are evidently related to the timing of substrate exposure and seed dispersal, and, therefore, vary annually.

25. Bank line orientation was important in determining plant establishment regardless of revetment type. Upper bends and eddies promoted plant community development, apparently by providing protection from scouring flows.

26. In general, riprap appears to be the best artificial substrate type for plant establishment, particularly for trees. Depth of the riprap blanket, although not measured, was observed to be an important influence on plant establishment. Little plant cover occurred in thick masses of riprap. It appeared that plant cover was greatest where only a single layer of rock was exposed; that is, sediments had filled all cavities below the surface layer, or only a single layer of rock was deposited on the soil surface. The latter situation was most frequently noted near the topbank.

27. Articulated concrete mat was often well-vegetated by plants that grew in the gaps between individual blocks. Cracks in asphalt paving also supported plants, but overall cover was lowest on this substrate type. Where riprap or articulated concrete mat was laid over asphalt, there was an increase in vegetation establishment. This increase probably resulted from increased sediment trapping and/or reduced scour.

PART V: SUMMARY

28. The vertical caving banks that once were common along the Lower Mississippi River have been largely replaced by sloping, armored banks that support varying degrees of vegetation cover. Three main types of artificial substrates are associated with revetment structures along the Lower Mississippi River: asphalt, articulated concrete mat, and riprap. Various combinations of these substrate types, as well as revetted areas covered by deep sediment deposits, are present. Riprap had the greatest amount of tree and herbaceous cover overall; however, herbaceous cover at low elevations was greater on articulated concrete mat substrates. Asphalt substrates were poorly colonized by plants from midway down the bankslope to the water. Plant cover increased with increasing bank elevation at most sites. Salix nigra and S. interior were the only tree species on the lower portion of the river bank. Vines made up a major portion of the ground cover at higher elevations and grew best on riprap. In general, vegetation establishment was highest on sites protected from scouring flows (upper bends, eddies, and on upper banks). Herbaceous plants and woody seedlings were sometimes abundant at lower elevations on the bank slope where sediment had accumulated. Such plant communities, however, are probably destroyed and replaced annually.

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Tuttle, J. R., and Pinner, W. 1982. "Analysis of Major Parameters Affecting the Behavior of the Mississippi River," Potamology Program Report 4, US Army Engineer Lower Mississippi Valley Division, Vicksburg, MS.

Table 1
Characteristics of 25 Revetted Sites Sampled on the Lower
Mississippi River in August 1985

River Mile*	Bank**	Year of Placement†	Bank Line Orientation‡	Number of Sample Plots‡						Total
				L	ML	M	MH	H	OB	
27.5	Right	1970	Straight	3	3	3	2	0	3	14
55.3	Right	1973	Straight	3	3	3	0	0	3	12
137.7	Left	1971	Straight	3	4	6	5	3	6	27
159.5	Left	1984	Straight	7	9	10	9	8	6	49
184.0	Left	1964	Concave apex	4	6	6	6	4	6	32
266.2	Right	1983	Concave apex	7	10	10	10	10	6	53
274.0	Right	1959	Lower bend	4	6	5	6	5	6	32
317.6	Right	1954	Lower bend	3	3	6	4	3	6	25
330.0	Right	1960	Upper bend	7	8	9	8	7	6	45
330.1	Right	1950	Concave apex	12	14	15	15	13	6	75
330.4	Right	1960	Upper bend	3	4	5	4	2	6	24
371.5	Right	1953	Straight	6	6	9	6	6	6	39
381.1	Right	1962	Lower bend	4	6	6	6	4	6	32
438.0	Right	1975	Convex apex	9	11	12	12	10	6	60
442.8	Right	1953	Concave apex	9	9	12	10	9	6	55
448.7	Right	1953	Lower bend	6	6	9	7	6	6	40
507.4	Left	1958	Straight	6	9	9	9	9	6	48
516.0	Left	1964	Eddy	9	10	12	11	10	6	58
535.7	Left	1958	Straight	6	6	7	7	6	6	38
565.5	Left	1960	Upper bend	6	9	9	9	7	6	46
568.0	Right	1963	Concave apex	8	10	11	11	9	6	55
572.5	Left	1957	Straight	7	9	10	9	9	6	50
572.7	Left	1957	Eddy	9	10	12	12	9	6	58
573.0	Left	1957	Straight	8	9	10	9	7	6	49
574.0	Left	1966	Concave apex	10	10	11	10	10	6	57
				159	190	217	197	166	144	1073

* Distance above Head of Passes, LA.

** Designated facing downstream.

† Construction dates as indicated by the Mississippi River Commission (1985)

‡ See Figure 1.

‡ Total number of plots for three transects at each sample site, by elevational segment. L = low, ML = mid-low, M = mid, MH = mid-high, H = high, OB = overbank.

Table 2

Number of Samples Associated with each Artificial Substrate Type by Elevation Zone

Substrate Type	Sample Distribution by Elevation Zone						Top* Bank	Grand Total
	Low	Mid-low	Middle	Mid-high	high	Revetment Total (Top bank excluded)		
Asphalt over articulated concrete mat	3	0	0	2	4	9	0	9
Asphalt	16	32	41	50	52	191	30	221
Articulated concrete mat over asphalt	9	9	12	4	0	34	6	40
Articulated concrete mat	68	54	59	30	15	226	28	254
Riprap over asphalt	15	19	18	5	9	66	20	86
Riprap over articulated concrete mat	1	1	1	3	0	6	12	18
Riprap	37	61	71	88	73	330	42	372
Unknown	10	14	15	15	13	67	6	73
Total	159	190	217	197	166	929	144	1073

* Top bank samples were taken in vegetated areas above the indicated predominant substrate type.

Table 3
Comparison of Means* for Each of Four Sample Variables across
Relative Bank Elevation Zones

<u>Variables</u>	<u>Means by Elevation Zone</u>					<u>Top Bank</u>
	<u>Low</u>	<u>Mid-low</u>	<u>Middle</u>	<u>Mid-high</u>	<u>High</u>	
Herb Cover, %	1.8e	4.9e	20.4d	35.1c	48.2b	83.1a
Canopy Cover, %	3.1c	5.8bc	12.6b	12.9b	25.2a	27.8a
Debris, %	0.6c	1.1bc	1.5abc	2.0ab	2.7a	2.8a
Substrate Depth, cm	6.6b	6.5b	7.0b	4.8b	5.9b	40.0a

* Within rows, means followed by the same letter are not significantly different ($p < 0.05$, Student-Newman-Keuls mean separation test).

Table 4
Pearson Correlation Coefficients for Selected Sample Variables
(Elevations Combined)

<u>Measurement</u>	<u>Ground Cover</u>	<u>Overstory Cover</u>	<u>Debris Cover</u>	<u>Sediment Depth</u>
River mile	-0.06	-0.04	0.00	-0.06
Sediment depth	-0.02	-0.10	-0.10	1.00
Age	0.11	0.06	0.07	-0.19
Slope %	-0.12	-0.14	-0.09	-0.38
Ground cover	1.00	0.17	0.11	-0.02

Table 5
Comparison of Variable Means* Among Substrate Types Within Each Bank Elevation Zone
and for Elevation Zones Within Each Substrate Type

Elevation Zone	Artificial Substrate Types**							
	AC N = 9 Plots	AS N = 191 Plots	CA N = 34 Plots	CM N = 226 Plots	RA N = 66 Plots	RM N = 6 Plots	RR N = 330 Plots	UN N = 67 Plots
	Ground Cover, %							
Low	0.0*/*	1.4*/c	0.2*/b	2.3*/b	2.7*/b	0.0*/*	1.1*/c	2.7*/*
Mid-low	-	0.6a/c	0.6a/b	10.1a/b	1.9a/b	0.0a/*	4.7a/c	2.4a/*
Middle	-	5.8a/c	19.9a/ab	33.7a/a	4.8a/b	5.0a/*	25.7a/b	3.2a/*
Mid-high	57.5a/*	25.6a/b	38.8a/a	40.4a/a	12.8a/b	43.3a/*	44.1a/a	4.2a/*
High	82.5a/*	64.5ab/a	-	34.3bc/a	48.9abc/a	-	43.6bc/a	14.bc/*
Top bank	-	82.8*/	99.2*/	70.9*/	89.4*/	84.6*/	85.6*/	85.0*/
Combined elevations	49.4a/	25.7b/	11.8b/	19.5b/	10.1b/	22.5b/	27.9b/	5.4b/

(Continued)

* Variable combinations represented by a dash (-) did not occur in the sample. Within rows, means followed by the same letter left of the slash are not significantly different ($p < 0.05$); within columns means followed by the same letter right of the slash are not significantly different ($p < 0.05$, Student-Newman-Keuls mean separation test). An asterisk (*) in either position indicates that no significant differences were detected by the F-test; therefore, no mean separation test was performed. The combined mean excludes the top bank zone. Both the combined and top bank zones were compared only across substrate types and were not included in elevation comparisons.

** Symbols: AC = Asphalt over articulated concrete mat, AS = Asphalt, CA = Articulated concrete over asphalt, CM = Articulated concrete mat, RA = Riprap over asphalt, RM = Riprap over articulated concrete mat, RR = Riprap, UN = Unknown

Table 5 (Continued)

Elevation Zone	Artificial Substrate Types							
	AC N = 9 Plots	AS N = 191 Plots	CA N = 34 Plots	CM N = 226 Plots	RA N = 66 Plots	RM N = 6 Plots	RR N = 330 Plots	UN N = 67 Plots
	<u>Overstory Cover, %</u>							
Low	33.3*/*	2.2*/*	0.0*/*	2.1*/b	0.0*/b	0.0*/*	5.7*/c	0.0*/*
Mid-low	-	4.1a/*	0.0a/*	0.3a/b	5.3a/ab	0.0a/*	14.0a/bc	0.0a/*
Middle	-	17.6a/*	0.0a/*	2.4a/b	10.6a/ab	0.0a/*	23.6a/ab	0.0a/*
Mid-high	0.0*/*	11.1*/*	0.0*/*	10.2*/b	1.0*/b	20.0*/*	18.3*/abc	0.0*/*
High	0.0b/*	16.9b/*	-	58.3a/a	25.0ab/a	-	30.1ab/a	0.0b/*
Top bank	-	36.8*/	35.0*/	30.2*/	37.3*/	1.7*/	26.1*/	0.0*/
Combined elevations	11.1a/	12.1a/	0.0a/	6.6a/	7.9a/	10.0a/	19.8a/	0.0a/
	<u>Debris Cover, %</u>							
Low	0.0*/*	0.1*/*	0.0*/*	0.9*/b	0.7*/b	0.0*/*	0.7*/*	0.0*/a
Mid-low	-	0.1a/*	0.2a/*	0.6a/b	2.5a/b	5.0a/*	2.7a/*	0.0a/a
Middle	-	0.3a/*	2.1a/*	0.6a/b	2.5a/b	5.0a/*	2.7a/*	0.0a/a
Mid-high	0.0b/*	0.7b/*	0.0b/*	2.5b/b	6.0b/a	13.3a/*	2.4b/*	0.0b/a
High	2.5*/*	1.4*/*	-	4.9*/a	0.4*/b	-	3.9*/*	0.5*/b
Top bank	-	3.5*/	3.3*/	3.5*/	2.5*/	5.8*/	1.1*/	2.3*/
Combined elevations	1.1b/	0.6b/	0.8b/	1.2b/	1.4b/	7.7a/	2.7b/	0.1b/

(Continued)

(Sheet 2 of 3)

Table 5 (Concluded)

Elevation Zone	Artificial Substrate Types							
	AC N = 9 Plots	AS N = 191 Plots	CA N = 34 Plots	CM N = 226 Plots	RA N = 66 Plots	RM N = 6 Plots	RR N = 330 Plots	UN N = 67 Plots
	<u>Sediment Depth, cm</u>							
Low	0.0b/a	0.0b/*	0.0b/*	9.2b/*	0.0b/*	0.0b/*	0.8b/*	39.0a/*
Mid-low	-	0.0b/*	0.0b/*	11.9b/*	0.3b/*	0.0b/*	0.3b/*	40.0a/*
Middle	-	0.3b/*	0.0b/*	12.3b/*	0.1b/*	0.0b/*	2.5b/*	40.0a/*
Mid-high	1.0b/a	0.0b/*	0.0b/*	8.1b/*	0.0b/*	0.0b/*	3.4b/*	40.0a/*
High	10.2-/a	0.2c/*	-	7.5bc/*	0.0c/*	-	4.1c/*	40.0a/*
Top bank	-	40.0*/	40.0*/	40.0*/	40.0*/	40.0*/	-	40.0*/
Combined elevations	4.8bc/	0.1c/	0.0c/	10.4b/	0.1c/	0.0c/	2.5c/	39.9a/
	<u>Slope, %</u>							
Low	19.3a/a	20.0a/*	17.3a/a	14.0a/*	18.7a/*	20.0a/*	18.6a/a	9.5a/*
Mid-low	-	19.0a/*	17.3a/a	12.3a/*	18.8a/*	20.0a/*	20.0a/a	10.9a/*
Middle	-	19.1a/*	17.3a/a	13.3a/*	19.0a/*	18.0a/*	16.9a/a	10.1a/*
Mid-high	6.5c/b	18.1ab/*	15.3abc/b	15.1abc*	19.2a/*	11.7abc/*	15.7abc/a	8.7bc/*
High	8.0b/b	18.6a/*	-	15.3ab/*	19.3a/*	-	12.5ab/b	9.8b/*
Top bank	-	7.0a/	7.0a/	8.8a/	5.2a/	1.3a/	3.9a/	3.0a/
Combined elevations	11.4cd/	18.8a/	17.1ab/	13.5bcd/	18.9a/	15.5abc/	15.8abc/	9.8d/

Table 5 (Concluded)

Elevation Zone	Artificial Substrate Types							
	AC N = 9 Plots	AS N = 191 Plots	CA N = 34 Plots	CM N = 226 Plots	RA N = 66 Plots	RM N = 6 Plots	RR N = 330 Plots	UN N = 67 Plots
	<u>Sediment Depth, cm</u>							
Low	0.0b/a	0.0b/*	0.0b/*	9.2b/*	0.0b/*	0.0b/*	0.8b/*	39.0a/*
Mid-low	-	0.0b/*	0.0b/*	11.9b/*	0.3b/*	0.0b/*	0.3b/*	40.0a/*
Middle	-	0.3b/*	0.0b/*	12.3b/*	0.1b/*	0.0b/*	2.5b/*	40.0a/*
Mid-high	1.0b/a	0.0b/*	0.0b/*	8.1b/*	0.0b/*	0.0b/*	3.4b/*	40.0a/*
High	10.2-/a	0.2c/*	-	7.5bc/*	0.0c/*	-	4.1c/*	40.0a/*
Top bank	-	40.0*/	40.0*/	40.0*/	40.0*/	40.0*/	-	40.0*/
Combined elevations	4.8bc/	0.1c/	0.0c/	10.4b/	0.1c/	0.0c/	2.5c/	39.9a/
	<u>Slope, %</u>							
Low	19.3a/a	20.0a/*	17.3a/a	14.0a/*	18.7a/*	20.0a/*	18.6a/a	9.5a/*
Mid-low	-	19.0a/*	17.3a/a	12.3a/*	18.8a/*	20.0a/*	20.0a/a	10.9a/*
Middle	-	19.1a/*	17.3a/a	13.3a/*	19.0a/*	18.0a/*	16.9a/a	10.1a/*
Mid-high	6.5c/b	18.1ab/*	15.3abc/b	15.1abc*	19.2a/*	11.7abc/*	15.7abc/a	8.7bc/*
High	8.0b/b	18.6a/*	-	15.3ab/*	19.3a/*	-	12.5ab/b	9.8b/*
Top bank	-	7.0a/	7.0a/	8.8a/	5.2a/	1.3a/	3.9a/	3.0a/
Combined elevations	11.4cd/	18.8a/	17.1ab/	13.5bcd/	18.9a/	15.5abc/	15.8abc/	9.8d/

Table 7
Frequency of Occurrence (Percent) of Tree and Large Shrub Species in Each Substrate Type by Elevation Zone
(Top bank Zone Excluded)

Species	Low				Mid-low				Middle				Mid-High				High			
	RR N = 37 Plots	RA N = 15 Plots	AS N = 16 Plots	CM N = 68 Plots	RR N = 61 Plots	RA N = 19 Plots	AS N = 32 Plots	CM N = 54 Plots	RR N = 71 Plots	RA N = 18 Plots	AS N = 41 Plots	CM N = 59 Plots	RR N = 88 Plots	RA N = 5 Plots	AS N = 50 Plots	CM N = 30 Plots	RR N = 73 Plots	RA N = 9 Plots	AS N = 52 Plots	CM N = 15 Plots
<u>Acer</u>																				
<u>negundo</u>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.4	0	0	6.7
<u>Amorpha</u>																				
<u>fruticosa</u>	0	0	0	0	0	0	0	0	1.4	5.6	14.6	5.1	5.7	0	0	6.7	8.2	0	1.9	6.7
<u>Carya</u>																				
<u>illinoensis</u>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.7	0	0	0
<u>Celtis</u>																				
<u>laevigata</u>	0	0	0	0	0	0	0	0	0	0	0	0	2.3	0	0	0	1.4	0	0	0
<u>Cephalanthus</u>																				
<u>occidentalis</u>	0	0	0	0	0	0	0	0	1.4	0	0	0	1.1	0	0	0	0	0	0	0
<u>Cornus</u>																				
<u>drummondii</u>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.4	0	0	0
<u>Fraxinus</u>																				
<u>pennsylvanica</u>	0	0	0	0	0	0	0	0	1.4	0	0	0	0	0	0	0	1.4	0	0	0
<u>Gleditsia</u>																				
<u>triacanthos</u>	0	0	0	0	0	0	0	0	0	0	0	0	1.1	0	0	0	1.4	0	0	0
<u>Liquidambar</u>																				
<u>styraciflua</u>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.4	0	0	0
<u>Platanus</u>																				
<u>occidentalis</u>	0	0	0	0	0	0	0	0	2.8	0	0	0	5.7	0	0	0	17.8	11.1	0	0
<u>Populus</u>																				
<u>deltoides</u>	0	0	0	0	0	0	0	0	2.8	0	0	0	1.1	0	0	0	1.4	0	0	0
<u>Salix</u>																				
<u>interior</u>	2.7	0	0	1.5	9.8	15.8	3.1	1.9	14.1	27.8	0	0	11.4	20.0	14.0	3.3	6.8	0	0	0
<u>Salix</u>																				
<u>nigra</u>	0	0	0	0	1.6	0	0	0	7.0	0	2.4	0	3.4	0	2.0	0	0	0	1.9	0
<u>Ulmus</u>																				
<u>rubra</u>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.4	0	0	0

Table 8

Number of Trees and Large Shrubs Encountered in Samples, by Species,
Size Class, and Elevation Zone

<u>Zone/Species</u>	<u>Number of Trees in Size Class, cm</u>			
	<u>0-5</u>	<u>5-15</u>	<u>15-25</u>	<u>>25</u>
Low elevation zone				
<u>Salix interior</u>	7	0	0	0
Mid-low elevation zone				
<u>Salix interior</u>	46	0	0	0
<u>Salix nigra</u>	0	3	1	0
Middle elevation zone				
<u>Amorpha fruticosa</u>	8	0	0	0
<u>Celtis laevigata</u>	1	0	0	0
<u>Cephalanthus occidentalis</u>	5	0	0	0
<u>Fraxinus pennsylvanica</u>	2	0	0	0
<u>Platanus occidentalis</u>	4	1	0	0
<u>Populus deltoides</u>	2	0	0	0
<u>Salix interior</u>	92	0	0	0
<u>Salix nigra</u>	6	2	2	0
Mid-upper zone				
<u>Amorpha fruticosa</u>	47	4	0	0
<u>Celtis laevigata</u>	3	0	0	0
<u>Gleditsia triacanthos</u>	1	0	0	0
<u>Platanus occidentalis</u>	7	4	0	0
<u>Populus deltoides</u>	0	1	0	0
<u>Salix interior</u>	71	2	0	0
<u>Salix nigra</u>	7	0	0	0
High elevation zone				
<u>Acer negundo</u>	3	0	0	0
<u>Amorpha fruticosa</u>	48	0	0	0
<u>Carya illinoensis</u>	3	0	0	0
<u>Celtis laevigata</u>	2	0	0	0
<u>Cornus drummondii</u>	1	0	0	0
<u>Fraxinus pennsylvanica</u>	1	0	0	0
<u>Liquidambar styraciflua</u>	2	0	0	0
<u>Gleditsia triacanthos</u>	1	0	0	0
<u>Platanus occidentalis</u>	37	6	0	2
<u>Populus deltoides</u>	0	0	0	1
<u>Salix interior</u>	12	1	0	0
<u>Salix nigra</u>	4	0	0	0
<u>Ulmus rubra</u>	1	0	0	0

(Continued)

Table 8 (Concluded)

Zone/Species	Number of Trees in Size Class, cm			
	0-5	5-15	15-25	>25
Top bank zone				
<u>Acer negundo</u>	3	16	10	2
<u>Amorpha fruticosa</u>	24	0	0	0
<u>Carya illinoensis</u>	0	1	10	15
<u>Celtis laevigata</u>	3	1	10	4
<u>Cornus drummondii</u>	8	0	0	0
<u>Fraxinus pennsylvanica</u>	7	9	4	2
<u>Gleditsia triacanthos</u>	5	3	2	1
<u>Maclura pomifera</u>	0	0	0	1
<u>Platanus occidentalis</u>	10	7	14	7
<u>Populus deltoides</u>	0	0	10	21
<u>Salix interior</u>	23	0	2	0
<u>Salix nigra</u>	9	4	66	48
<u>Ulmus rubra</u>	3	2	0	0

Elevations combined

<u>Acer negundo</u>	6	16	10	2
<u>Amorpha fruticosa</u>	127	4	0	0
<u>Carya illinoensis</u>	3	1	10	15
<u>Celtis laevigata</u>	8	1	12	4
<u>Cephalanthus occidentalis</u>	5	0	0	0
<u>Cornus drummondii</u>	9	0	0	0
<u>Fraxinus pennsylvanica</u>	10	9	4	2
<u>Gleditsia triacanthos</u>	7	3	2	1
<u>Liquidamber styraciflua</u>	2	0	0	0
<u>Maclura pomifera</u>	0	0	0	1
<u>Platanus occidentalis</u>	58	18	15	9
<u>Populus deltoides</u>	2	1	12	25
<u>Salix interior</u>	251	3	2	0
<u>Salix nigra</u>	26	9	76	49
<u>Ulmus rubra</u>	4	2	0	0

Table 9

Number of Plots of Occurrence and Total Number of Woody Seedlings
Sampled, by Species and Elevation Zone

Species	Number of Plots of Occurrence							Total No. of Seedlings
	Low	Mid- low	Middle	Mid- high	High	Top Bank	Total	
<u>Acer negundo</u>	0	0	0	1	0	0	1	4
<u>Amorpha fruticosa</u>	0	2	0	3	3	4	12	67
<u>Carya illinoensis</u>	0	0	0	1	1	0	2	2
<u>Celtis laevigata</u>	0	0	3	4	2	6	15	34
<u>Cephalanthus</u>								
<u>occidentalis</u>	0	1	0	0	0	0	1	1
<u>Cornus drummondii</u>	0	0	0	0	0	3	3	7
<u>Diospyros virginiana</u>	0	0	0	0	1	1	2	5
<u>Gleditsia triacanthos</u>	0	0	0	0	0	1	1	1
<u>Nyssa sylvatica</u>	0	0	0	1	0	0	1	1
<u>Platanus occidentalis</u>	0	0	0	1	0	0	1	1
<u>Populus deltoides</u>	0	5	11	13	3	8	40	205
<u>Quercus nuttallii</u>	0	0	2	0	0	1	3	3
<u>Salix interior</u>	7	14	18	7	1	1	48	121
<u>Salix nigra</u>	5	12	20	8	7	12	64	430
<u>Ulmus rubra</u>	0	0	1	0	1	0	2	2

Table 10

Number of Plots of Occurrence and Total Number of Canopy Vines
Sampled, by Species and Elevation Zone

Species	Number of Plots of Occurrence							Total No. Vines
	Low	Mid- low	Middle	Mid- High	High	Top Bank	Total	
<u>Ampelopsis arborea</u>	0	1	1	2	4	6	14	55
<u>Brunnichia cirrhosa</u>	0	0	1	1	0	2	4	13
<u>Campsis radicans</u>	0	0	2	3	3	7	15	47
<u>Cocculus caroliniana</u>	0	0	0	0	0	2	2	2
<u>Cynanchum laeve</u>	0	0	0	0	0	1	1	1
<u>Ipomoea pandurata</u>	0	0	1	0	0	0	1	1
<u>Rhus radicans</u>	0	0	0	0	0	2	2	5
<u>Smilax rotundifolia</u>	0	0	0	0	0	1	1	5
<u>Strophostyles helvola</u>	0	0	0	2	1	4	7	22
<u>Trachaelospermum</u>								
<u>difforme</u>	0	0	0	0	0	1	1	10
<u>Vitis cinerea</u>	0	0	0	1	0	0	1	1
<u>Vitis riparia</u>	0	0	0	0	1	1	2	31

Table 11
Number of Plots of Occurrence, by Elevation Zone, and Mean
Cover for Ground Cover Species, Arranged in Order of
Decreasing Frequency of Occurrence

Species	Number of Plots of Occurrence						Mean Cover, %	
	Low	Mid-low	Middle	Mid-high	High	Total	Plots of occurrence	All Plots
Very important species								
<u>Campsis radicans</u>	0	4	27	55	57	143	51	7.9
<u>Cyperus esculentus</u>	5	19	25	45	28	122	27	3.5
<u>Strophostyles helvola</u>	2	6	27	45	75	105	50	5.7
<u>Ipomoea pandurata</u>	3	13	21	29	37	103	49	5.5
<u>Xanthium strumarum</u>	6	8	19	32	29	94	48	4.9
<u>Panicum capillare</u>	6	7	20	26	18	77	45	3.8
<u>Euphorbia maculata</u>	1	4	9	25	34	73	48	3.8
<u>Digitaria sanguinalis</u>	2	5	14	22	21	64	50	3.4
<u>Amaranthus tamariscinus</u>	16	16	14	10	7	63	31	2.1
<u>Desmanthus illinoensis</u>	1	1	8	25	26	61	61	4.0
<u>Rubus trivialis</u>	0	0	7	17	36	60	58	3.8
<u>Salix nigra</u>	4	13	19	10	7	53	47	2.7
<u>Ampelopsis arborea</u>	0	2	9	14	26	51	56	3.1
<u>Eclipta alba</u>	6	13	13	10	7	49	45	2.4
<u>Sorghum halepense</u>	0	0	4	19	21	44	52	2.5
<u>Brunnichia cirrhosa</u>	1	5	9	11	17	43	56	2.6
<u>Rhus radicans</u>	0	1	2	7	28	38	55	2.2
Important species								
<u>Salix interior</u>	7	21	16	6	1	51	17	0.9
<u>Molugo verticillata</u>	8	17	12	7	5	49	30	1.6
<u>Fimbristylis vahlII</u>	10	11	9	5	3	38	28	1.2
<u>Eragrostis hypnoides</u>	8	11	11	3	0	33	32	1.2
<u>Panicum dichotomiflorum</u>	4	3	5	12	9	33	50	1.8
<u>Populus deltoides</u>	0	5	11	13	3	32	53	1.8
<u>Leptochloa filiformes</u>	3	7	12	7	1	30	46	1.5
<u>Euphorbia supina</u>	0	0	2	11	13	26	49	1.4
<u>Mimosa strililgosa</u>	0	0	4	5	14	23	59	1.5
<u>Cynodon dactylon</u>	1	1	3	6	10	21	58	1.3
<u>Sesbania exaltata</u>	1	2	4	8	6	21	55	1.2
<u>Croton capitatus</u>	1	1	7	8	3	20	45	1.0
<u>Euphorbia humistrata</u>	1	0	5	4	7	17	50	0.9
<u>Lindernia anagallidea</u>	1	4	8	3	1	17	45	0.8
<u>Phyla incisa</u>	1	1	4	9	2	17	49	0.9
<u>Cynanchum laeve</u>	0	2	5	6	3	16	53	0.9
<u>Leucosporum multifida</u>	1	3	4	4	4	16	49	0.8
<u>Amaranthus sp.</u>	0	2	5	5	3	15	68	1.1

(Continued)

(Sheet 1 of 3)

Table 11 (Continued)

Species	Number of Plots of Occurrence						Mean Cover, %	
	Low	Mid-low	Middle	Mid-high	High	Total	Plots of occurrence	All Plots
Common Species								
<u>Ammannia coccinea</u>	2	4	7	1	0	14	41	0.6
<u>Desmodium paniculata</u>	0	0	1	5	7	13	49	0.7
<u>Eragrostis pectinacea</u>	0	6	5	2	0	13	43	0.6
<u>Echinochloa colonum</u>	0	1	3	6	2	12	37	0.5
<u>Amorpha fruticosa</u>	0	2	0	4	4	10	47	0.5
<u>Cyperus rotundus</u>	0	0	2	5	3	10	32	0.3
<u>Celtis laevigata</u>	0	0	3	4	2	9	31	0.3
<u>Vitis cinerea</u>	0	0	1	4	4	9	61	0.6
<u>Cardiospermum halicacabum</u>	0	1	0	4	3	8	33	0.3
<u>Diospyros virginiana</u>	0	0	1	3	4	8	51	0.4
<u>Iva annua</u>	0	0	0	2	6	8	73	0.6
Unknown forb	2	1	1	2	2	8	28	0.2
<u>Asclepias sp.</u>	0	1	3	1	2	7	73	0.6
<u>Digitaria ischaemum</u>	0	0	1	1	5	7	65	0.5
<u>Heliotropium indicum</u>	3	1	0	3	0	7	31	0.2
<u>Ludwigia decurrens</u>	1	1	4	1	0	7	33	0.3
<u>Pluchea camphorata</u>	0	0	5	2	0	7	72	0.5
<u>Schrankia microphylla</u>	0	0	0	5	2	7	40	0.3
Unknown graminoid	4	1	1	1	0	7	13	0.1
<u>Acalypha rhomboidea</u>	0	0	2	3	1	6	39	0.3
<u>Cuscuta gronovii</u>	0	0	1	0	5	6	74	0.5
<u>Leersia virginiana</u>	0	0	3	3	0	6	50	0.3
<u>Vitus riparia</u>	0	0	1	0	5	6	56	0.4
<u>Aster simplex</u>	0	0	3	1	1	5	63	0.3
<u>Heliotropium sp.</u>	0	0	1	2	2	5	44	0.2
<u>Rorippa sessiliflora</u>	2	2	0	0	1	5	29	0.2
<u>Setaria geniculata</u>	0	0	0	2	3	5	51	0.3
<u>Solanum carolinense</u>	0	0	3	1	1	5	50	0.3
<u>Aster sp.</u>	0	0	0	0	4	4	65	0.3
<u>Colocasia antiquorum</u>	0	1	2	1	0	4	65	0.3
<u>Hibiscus militaris</u>	1	0	1	1	1	4	20	0.1
Unknown pea	0	0	0	1	3	4	42	0.2
<u>Zizaniopsis millacea</u>	0	1	3	0	0	4	58	0.3
<u>Artemisia annua</u>	0	0	1	0	2	3	43	0.1
<u>Commelina virginiana</u>	0	0	0	3	0	3	46	0.2
<u>Cucurbita sp</u>	0	0	0	2	1	3	76	0.2
<u>Cyperus erithrorizos</u>	0	1	1	1	0	3	29	0.1
<u>Cyperus sp.</u>	1	1	1	0	0	3	9	0.1
<u>Eragrostis sp.</u>	0	0	2	1	0	3	56	0.2
<u>Platanus occidentalis</u>	0	0	0	2	1	3	45	0.1
<u>Rotala ramosior</u>	1	0	1	0	1	3	65	0.2
<u>Setaria glauca</u>	0	0	0	1	2	3	59	0.2

(Continued)

(Sheet 2 of 3)

Table 11 (Concluded)

Incidental species

Occurred twice	Occurred once
<u>Alternanthera philoxeroides</u>	<u>Acer negundo</u>
<u>Ambrosia artemisiifolia</u>	<u>Ambrosia trifida</u>
<u>Bohemeria cylindrica</u>	<u>Apocynum cannabinum</u>
<u>Carya illinoensis</u>	<u>Aster tenuifolius</u>
<u>Cephalanthus occidentalis</u>	<u>Cocculus carolinus</u>
<u>Cyperus strigosus</u>	<u>Cyperus inferior</u>
<u>Echinochloa crusgalli</u>	<u>Equisetum hyemale</u>
<u>Eragrostis ciliaris</u>	<u>Fimbristylis autumnalis</u>
<u>Eragrostis pilosa</u>	<u>Leersia sp.</u>
<u>Euphorbia sp.</u>	<u>Ludwigia sp.</u>
<u>Leucospora virginiana</u>	<u>Nyssa sylvatica</u>
<u>Paspalum fluitans</u>	<u>Oxalis stricta</u>
<u>Quercus nuttallii</u>	<u>Panicum repens</u>
<u>Spilanthes americana</u>	<u>Panicum sp.</u>
<u>Trachelospermum difforme</u>	<u>Parthenocissus quinquefolia</u>
<u>Ulmus rubra</u>	<u>Physalis pubescens</u>
Unknown forb	<u>Portulacca oleracea</u>
	<u>Sida spinosa</u>
	<u>Smilax bona-nox</u>
	<u>Smilax sp.</u>
	<u>Sporobolus sp.</u>
	<u>Teucrium canadense</u>
	Unknown forb
	<u>Verbena urticifolia</u>

Table 12
Frequency of Occurrence (Percent) and Mean Percent Cover of the "Very Important"
Ground Cover Species in Each Substrate Type, by Elevation Zone*

Zone/Species	Frequency, %						Mean Cover, %					
	RR N = 37 Plots	CM N = 68 Plots	AS N = 16 Plots	RA N = 15 Plots	UN N = 10 Plots	CA N = 9 Plots	RR N = 37 Plots	CM N = 68 Plots	AS N = 16 Plots	RA N = 15 Plots	UN N = 10 Plots	CA N = 9 Plots
Low elevation												
<u>Amaranthus tamariscinus</u>	8.1	11.8	0	0	50.0	0	0.7	1.5	0	0	2.0	0
Mid-low elevation	(N = 61)	(N = 54)	(N = 32)	(N = 19)	(N = 14)	(N = 9)	(N = 61)	(N = 54)	(N = 32)	(N = 19)	(N = 14)	(N = 9)
<u>Amaranthus tamariscinus</u>	1.6	22.2	0	10.5	7.1	0	0.2	5.0	0	0.5	0.2	0
<u>Cyperus esculentus</u>	3.3	16.7	0	0	57.1	0	0.2	3.1	0	0	2.1	0
<u>Eclipta alba</u>	1.6	20.4	0	5.3	0	0	0.0	5.8	0	1.3	0	0
<u>Ipomoea pandurata</u>	13.1	3.7	3.1	5.3	0	11.1	0.9	1.0	0.1	0.4	0	0.1
<u>Salix nigra</u>	3.3	20.4	0	0	0	0	0.2	4.2	0	0	0	0
Middle elevation	(N = 71)	(N = 59)	(N = 41)	(N = 18)	(N = 15)	(N = 12)	(N = 71)	(N = 59)	(N = 41)	(N = 18)	(N = 15)	(N = 12)
<u>Amaranthus tamariscinus</u>	2.8	16.9	0	11.1	0	0	0.7	6.2	0	3.3	0	0
<u>Campsis radicans</u>	25.4	1.7	17.1	5.6	0	0	10.1	0.0	2.7	0	0	0
<u>Cyperus esculentus</u>	1.4	15.3	14.6	11.1	46.7	0	9.7	6.4	2.9	0.1	3.1	0
<u>Digitaria sanguinalis</u>	8.5	5.1	2.4	5.6	0	25.0	3.2	4.2	0.2	0.3	0	12.9
<u>Eclipta alba</u>	5.6	13.6	0	0	6.7	0	1.2	7.3	0.0	0	0	0
<u>Ipomoea pandurata</u>	19.7	8.5	0	5.6	0	25.0	7.8	5.3	0	1.1	0	11.0
<u>Panicum capillare</u>	9.9	16.9	0	5.6	0	8.3	2.9	7.8	0	1.7	0	4.2
<u>Salix nigra</u>	4.2	23.7	0	0	0	8.3	1.5	13.2	0	0	0	4.2
<u>Strophostyles helvola</u>	23.9	16.9	0	0	0	0	11.2	13.8	0	0	0	0
<u>Xanthium strumarum</u>	15.5	8.5	0	11.1	0	8.3	6.6	3.7	0	1.4	0	1.0
Mid-high elevation	(N = 88)	(N = 30)	(N = 50)	(N = 5)	(N = 15)	(N = 4)	(N = 88)	(N = 30)	(N = 50)	(N = 5)	(N = 15)	(N = 4)
<u>Amaranthus tamariscinus</u>	4.5	20.0	0	0	0	0	2.3	15.0	0	0	0	0
<u>Ampelopsis arborea</u>	9.1	0	12.0	0	0	0	5.7	0	4.4	0	0	0
<u>Brunnichia cirrhosa</u>	8.0	13.3	0	0	0	0	4.1	10.5	0	0	0	0
<u>Campsis radicans</u>	33.0	33.3	26.0	20.0	0	0	16.4	14.3	12.0	8.0	0	0
<u>Cyperus esculentus</u>	6.8	26.7	40.0	0	6.7	25.0	3.0	12.4	13.7	0	4.2	12.5
<u>Desmanthus illinoensis</u>	14.8	6.7	14.0	0	0	50.0	9.7	4.0	6.5	0	0	37.5
<u>Digitaria sanguinalis</u>	9.1	20.0	16.0	0	0	0	5.9	12.5	7.1	0	0	0
<u>Eclipta alba</u>	4.5	20.0	0	0	0	0	1.6	17.0	0	0	0	0
<u>Euphorbia maculata</u>	12.5	0	26.0	0	0	0	7.3	0	7.0	0	0	0
<u>Ipomoea pandurata</u>	22.7	6.7	10.0	0	0	25.0	11.8	6.7	4.5	0	0	25.0
<u>Panicum capillare</u>	20.5	13.3	2.0	20.0	0	25.0	10.7	5.8	0.5	1.6	0	25.0
<u>Rhus radicans</u>	3.4	13.3	0	0	0	0	2.1	7.3	0	0	0	0
<u>Rubus trivialis</u>	14.8	0	8.0	0	0	0	6.8	0	3.0	0	0	0

(Continued)

Table 12 (Concluded)

Zone/Species	Frequency, %						Mean Cover, %					
	RR (N = 88) Plots	CM (N = 30) Plots	AS (N = 50) Plots	RA (N = 5) Plots	UN (N = 15) Plots	CA (N = 4) Plots	RR (N = 88) Plots	CM (N = 30) Plots	AS (N = 50) Plots	RA (N = 5) Plots	UN (N = 15) Plots	CA (N = 4) Plots
Mid-high elevation (cont.)												
<u>Salix nigra</u>	5.7	16.7	0	0	0	0	2.6	14.8	0	0	0	0
<u>Sorghum halepense</u>	9.1	3.3	16.0	20.0	0	0	4.5	0.7	4.0	1.6	0	0
<u>Strophostyles helvola</u>	44.3	6.7	0	20.0	0	0	21.9	4.0	0	8.0	0	0
<u>Xanthium strumarum</u>	25.0	13.3	6.0	0	0	75.0	12.3	12.7	2.5	0	0	38.8
High elevation	(N = 73)	(N = 15)	(N = 52)	(N = 9)	(N = 13)	(N = 0)	(N = 73)	(N = 15)	(N = 52)	(N = 9)	(N = 13)	(N = 0)
<u>Ampelopsis arborea</u>	8.2	0	30.8	44.4	0	-	3.9	0	24.5	18.9	0	-
<u>Brunnichia cirrhosa</u>	12.3	20.0	3.8	33.3	0	-	8.6	11.3	3.8	18.9	0	-
<u>Campsis radicans</u>	30.1	33.3	42.3	66.7	0	-	19.9	14.7	32.6	36.7	0	-
<u>Cyperus esculentus</u>	13.7	33.3	7.7	0	69.2	-	5.3	21.0	2.1	0	14.7	-
<u>Desmanthus illinoensis</u>	16.4	0	26.9	0	0	-	9.4	0	23.2	0	0	-
<u>Digitaria sanguinalis</u>	11.0	13.3	17.3	11.1	7.7	-	5.4	8.7	12.0	4.4	3.8	-
<u>Euphorbia maculata</u>	13.7	6.7	42.3	11.1	0	-	7.3	4.7	29.8	2.8	0	-
<u>Ipomoea pandurata</u>	27.4	26.7	17.3	22.2	0	-	13.7	17.7	15.7	5.6	0	-
<u>Panicum capillare</u>	15.1	6.7	9.6	11.1	0	-	9.6	6.3	6.7	6.7	0	-
<u>Rhus radicans</u>	13.7	40.0	17.3	33.3	0	-	7.8	13.3	12.0	17.8	0	-
<u>Rubus trivialis</u>	26.0	0	23.1	55.6	0	-	17.7	0	16.7	33.9	0	-
<u>Sorghum halepense</u>	17.8	0	9.6	33.3	0	-	11.6	0	7.3	18.9	0	-
<u>Strophostyles helvola</u>	31.5	0	1.9	11.1	0	-	18.3	0	1.4	2.8	0	-
<u>Xanthium strumarum</u>	19.2	13.3	13.5	11.1	15.4	-	11.2	10.0	11.1	4.4	8.4	-

* Substrate types: RR = riprap, CM = articulated concrete mat, AS = asphalt, RA = riprap over asphalt, UN = unknown-deep sediments present, CA = articulated concrete mat over asphalt. Two other types, asphalt over articulated concrete mat and riprap over articulated concrete mat, were excluded because of the small number of occurrences.

Table 13
Mean Values* for Selected Variables, by River Mile
(Top Bank Zone Excluded)

<u>River Mile</u>	<u>N</u>	<u>Ground Cover, %</u>	<u>Overstory Cover, %</u>	<u>Debris, %</u>	<u>Sediment Depth, cm</u>	<u>Slope, %</u>
27.5	11	36.3abcd	87.3a	7.8a	11.0d	1.6j
55.3	9	28.9abcde	32.8bcd	6.4a	13.3d	2.3j
137.7	21	47.1ab	30.2bcd	1.3b	0.2e	13.2gh
159.5	43	27.5abcde	0.0e	0.3b	2.0e	10.2hi
184.0	26	32.2abcde	40.4b	1.5b	0.3e	17.9cdef
266.2	47	18.8cde	0.2e	1.9b	0.3e	15.8efg
274.0	26	20.5bcde	0.0e	0.7b	0.1e	21.7b
317.6	19	20.1bcde	0.3e	0.6b	1.8e	21.5bc
330.0	39	17.0de	1.3e	1.8b	1.4e	8.9i
330.1	69	5.4e	0.0e	0.1b	39.6a	9.8hi
330.4	18	49.4a	0.0e	0.3b	32.3c	11.8hi
371.5	33	12.8de	5.4e	1.2b	0.2e	19.9bcd
381.1	26	32.4abcd	12.1e	2.5b	0.2e	20.8bcd
438.0	54	24.3abcde	19.3cde	3.2b	0.9e	15.1fg
442.8	49	28.2abcde	3.1e	0.6b	0.0e	16.1efg
448.7	34	16.9de	16.5de	0.2b	0.1e	17.9cdef
507.4	42	8.6de	8.8e	0.0b	0.0e	17.4def
516.0	52	20.7bcde	36.1bc	1.3b	2.5e	11.9hi
535.7	32	25.6abcde	1.6e	1.4b	0.1e	28.9a
565.5	40	45.6abc	32.0bcd	7.1a	0.3e	15.2fg
568.0	49	20.3bcde	2.0e	0.1b	0.0e	20.0bcd
572.5	44	16.9de	3.5e	1.6b	0.0e	19.3bcde
572.7	52	18.2cde	20.7cde	2.1b	2.2e	17.7def
573.0	43	9.7de	15.8de	2.2b	0.1e	19.1bcde
574.0	51	28.2abcde	3.8e	0.9b	36.3b	10.3hi

* Within columns, means followed by the same letter are not significantly different ($p < 0.0001$, Student-Newman-Keuls mean separation test).

Table 14
Mean Values* for Selected Variables, by Revetment
Construction Date (Top Bank Zone Excluded)

<u>Construction Date**</u>	<u>N</u>	<u>Ground Cover, %</u>	<u>Overstory Cover, %</u>	<u>Debris Cover, %</u>	<u>Soil Depth, cm</u>	<u>Slope, %</u>
1950	70	6.4c	0.0d	0.1b	39.6a	9.9h
1953	116	20.5bc	7.7d	0.6b	0.1d	17.7cde
1954	19	20.1bc	0.3d	0.6b	1.8cd	21.5ab
1957	139	15.2bc	13.7d	1.9b	0.8d	18.6bcd
1958	74	15.9bc	5.7d	0.6b	0.1d	22.4a
1959	26	20.5bc	0.0d	0.6b	0.1d	21.7ab
1960	96	34.4ab	13.9d	3.7b	6.3c	12.0gh
1962	26	32.4abc	12.1d	2.5b	0.2d	20.8abc
1963	49	20.3bc	2.0d	0.1b	0.0d	20.0abc
1964	78	24.6abc	37.5b	1.4b	1.8cd	13.9fg
1966	51	28.2abc	3.8d	0.9b	36.3a	10.3h
1970	11	36.4ab	87.3a	7.8a	11.0b	1.6i
1971	21	47.1a	30.2bc	1.3b	0.2d	13.2fgh
1973	9	28.9abc	32.8bc	6.4a	13.3b	2.3i
1975	54	24.3abc	19.3cd	3.2b	0.7d	15.1efg
1983	47	18.8bc	0.2d	1.9b	0.3d	15.8def
1984	43	27.5abc	0.0d	0.3b	2.0cd	10.2h

* Within columns, means followed by the same letter are not significantly different ($p < 0.0001$, Student-Newman-Keuls mean separation test).

** Construction dates may not reflect more recent additions of materials when repairs have occurred.

Table 15
Comparison of Mean Values* for Selected Variables by Elevation
and Bank Line Orientation

<u>Elevation Zone</u>	<u>Upper Bend N = 97 Plots</u>	<u>Concave Apex N = 291 Plots</u>	<u>Lower Bend N = 105 Plots</u>	<u>Straight N = 278 Plots</u>	<u>Eddy N = 104 Plots</u>	<u>Convex Apex N = 54 Plots</u>
<u>Ground Cover, %</u>						
Low	0.0*	3.0*	3.9*	1.5*	0.1*	0.2*
Mid-low	9.9*	5.5*	2.3*	3.0*	6.0*	4.4*
Middle	33.6b	12.8c	7.8c	22.1bc	16.7bc	61.8a
Mid-high	61.3a	34.7b	32.8b	28.9b	37.0b	20.0b
High	69.4a	44.6ab	70.1a	46.9ab	34.2b	27.9b
Top bank	82.4a	78.9a	95.4a	85.5a	60.0b	89.2a
Combined Mean**	34.8a	20.3b	22.2b	20.2b	19.5b	24.3b
<u>Overstory Cover, %</u>						
Low	0.0*	2.0*	2.1*	7.2*	0.0*	0.0*
Mid-low	2.4*	3.9*	8.8*	8.4*	7.5*	0.0*
Middle	14.1*	5.7*	11.5*	16.6*	19.8*	11.8*
Mid-high	24.0ab	3.9c	7.6bc	10.5bc	35.9a	16.8bc
High	28.1b	10.3b	10.3b	16.3b	78.9a	70.0a
Top bank	26.9b	20.0b	10.3b	36.7ab	60.4a	11.7b
Combined Mean**	13.0bc	5.2c	8.3c	12.0bc	28.3a	19.3b
<u>Debris Cover, %</u>						
Low	2.4a	0.2b	0.4b	0.7b	0.2b	0.6b
Mid-low	2.4a	0.5a	0.6a	1.8a	0.3a	0.0a
Middle	1.9*	1.2*	2.0*	1.9*	0.6*	0.0*

(Continued)

Table 15 (Concluded)

	Upper Bend N = 97	Concave Apex N = 291	Lower Bend N = 105	Straight N = 278	Eddy N = 104	Convex Apex N = 54
<u>Elevation Zone</u>	<u>Plots</u>	<u>Plots</u>	<u>Plots</u>	<u>Plots</u>	<u>Plots</u>	<u>Plots</u>
Mid-high	5.3b	0.6c	1.3bc	1.2bc	1.9bc	8.8a
High	7.3a	1.2bc	0.1c	2.0abc	5.9ab	6.0ab
Top bank	5.3	2.3	0.5	3.5	3.8	0.2
Combined Mean**	3.7a	0.7b	0.9b	1.5b	1.7b	3.1a
<u>Sediment Depth, cm</u>						
Low	0.0b	18.8a	0.7b	0.6b	3.5b	0.7b
Mid-low	5.2b	17.4a	0.5b	0.4b	2.1b	0.7b
Middle	9.2ab	16.5a	0.3b	2.8b	0.8b	1.0b
Mid-high	8.7ab	13.7a	0.1b	1.5b	1.0b	0.0b
High	8.9ab	12.9a	0.6b	0.3b	5.3ab	1.0b
Top bank	40.0*	40.0*	40.0*	40.0*	40.0*	40.0*
Combined Mean**	6.6b	15.8a	0.4c	1.2c	2.3c	0.6c
<u>Slope, %</u>						
Low	12.1b	14.9ab	19.5a	18.1a	14.7ab	16.1ab
Mid-low	13.1b	14.7ab	19.1a	16.9ab	15.7ab	13.5b
Middle	13.2bc	14.7bc	20.8a	17.2b	16.0bc	12.3c
Mid-high	11.2c	14.2bc	19.5a	17.6ab	14.1bc	17.5ab
High	10.1b	13.4b	22.2a	15.2b	13.4b	16.4b
Top bank	6.7a	3.6a	8.6a	3.5a	10.8a	6.7a
Combined Mean**	12.0d	14.3c	20.2a	17.1b	14.8c	15.1c

* Within rows, means followed by the same letter are not significantly different ($p < 0.01$, Student-Newman-Keuls mean separation test). An asterisk (*) indicates that no significant differences were detected by the F-test.

** Combined mean does not include topbank zone.

APPENDIX A: SCIENTIFIC AND COMMON NAMES OF PLANT SPECIES

<u>Scientific Name</u>	<u>Common Name</u>
<u>Acalypha rhomboidea</u>	Three-seeded mercury
<u>Acer negundo</u>	Boxelder
<u>Alternanthera philoxeroides</u>	Alligatorweed
<u>Amaranthus tamariscinus</u>	Pigweed
<u>Ambrosia artemisiifolia</u>	Common ragweed
<u>Ambrosia trifida</u>	Giant ragweed
<u>Ammannia coccinea</u>	Toothcup
<u>Amorpha fruticosa</u>	Leadplant
<u>Ampelopsis arborea</u>	Peppervine
<u>Apocynum cannabinum</u>	Dogbane
<u>Artemisia annua</u>	Sweet wormwood
<u>Asclepias sp.</u>	Milkweed
<u>Aster simplex</u>	Tall white aster
<u>Aster tenuifolius</u>	Aster
<u>Boehmeria cylindrica</u>	False-nettle
<u>Brunnichia cirrhosa</u>	Ladies'-eardrops
<u>Campsis radicans</u>	Trumpet creeper
<u>Cardiospermum halicacabum</u>	Balloon vine
<u>Carya illinoensis</u>	Pecan
<u>Celtis laevigata</u>	Sugarberry
<u>Cephalanthus occidentalis</u>	Buttonbush
<u>Cocculus carolinus</u>	Snailseed
<u>Colocasia antiquorum</u>	Elephant ear
<u>Commelina virginica</u>	Dayflower
<u>Cornus drummondii</u>	Roughleaf dogwood
<u>Croton capitatus</u>	Wooly croton
<u>Cucurbita sp.</u>	Squash
<u>Cuscuta gronovii</u>	Dodder
<u>Cynanchum laeve</u>	Climbing milkweed
<u>Cynodon dactylon</u>	Bermuda grass
<u>Cyperus erithrorhizos</u>	Redroot sedge

(Continued)

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<u>Scientific Name</u>	<u>Common Name</u>
<u>Cyperus esculentus</u>	Chufa
<u>Cyperus inferior</u>	Sedge
<u>Cyperus rotundus</u>	Sedge
<u>Cyperus strigosus</u>	Sedge
<u>Desmanthus illinoensis</u>	Bundleflower
<u>Desmodium paniculatum</u>	Beggar's tick
<u>Digitaria ischaemum</u>	Crabgrass
<u>Digitaria sanguinalis</u>	Crabgrass
<u>Diospyros virginiana</u>	Persimmon
<u>Echinochloa colonum</u>	Barnyardgrass
<u>Echinochloa crus-galli</u>	Barnyardgrass
<u>Eclipta alba</u>	Eclipta
<u>Equisetum hyemale</u>	Horsetail
<u>Eragrostis ciliaris</u>	Lovegrass
<u>Eragrostis hypnoides</u>	Lovegrass
<u>Eragrostis pectinacea</u>	Lovegrass
<u>Eragrostis pilosa</u>	Lovegrass
<u>Euphorbia humistrata</u>	Spurge
<u>Euphorbia maculata</u>	Nodding spurge
<u>Euphorbia supina</u>	Milk purslane
<u>Fimbristylis autumnalis</u>	Fimbristylis
<u>Fimbristylis vahlII</u>	Fimbristylis
<u>Fraxinus pennsylvanica</u>	Green ash
<u>Gleditsia triacanthos</u>	Honey locust
<u>Heliotropium indicum</u>	Heliotrope
<u>Hibiscus militaris</u>	Rose mallow
<u>Ipomoea pandurata</u>	Wild potato vine
<u>Iva annua</u>	Marsh-elder
<u>Leersia virginica</u>	Cutgrass
<u>Leptochloa filiformes</u>	Sprangletop
<u>Leucospora multifida</u>	Leucospora
<u>Leucospora virginiana</u>	Leucospora
<u>Lindernia anagallidea</u>	False pimpernel

(Continued)

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<u>Scientific Name</u>	<u>Common Name</u>
<u>Liquidambar styraciflua</u>	Sweetgum
<u>Ludwigia decurrens</u>	Ludwigia
<u>Maclura pomifera</u>	Osage orange
<u>Mimosa strigillosa</u>	Mimosa
<u>Mollugo verticillata</u>	Carpetweed
<u>Nyssa sylvatica</u>	Blackgum
<u>Oxalis stricta</u>	Sorrel
<u>Panicum capillare</u>	Panic grass
<u>Panicum dichotimoflorum</u>	Panic grass
<u>Panicum repens</u>	Panic grass
<u>Parthenocissus quinquefolia</u>	Virginia creeper
<u>Paspalum fluitans</u>	Paspalum
<u>Phyla incisa</u>	Phyla
<u>Physalis pubescens</u>	Groundcherry
<u>Platanus occidentalis</u>	Sycamore
<u>Pluchea camphorata</u>	Marsh fleaba
<u>Populus deltoides</u>	Cottonwood
<u>Portulacca oleracea</u>	Common purslane
<u>Quercus nuttallii</u>	Nuttall oak
<u>Rhus radicans</u>	Poison ivy
<u>Rorippa sessiliflora</u>	Yellow cress
<u>Rotala ramosior</u>	Rotala
<u>Rubus trivialis</u>	Dewberry
<u>Salix interior</u>	Sandbar willow
<u>Salix nigra</u>	Black willow
<u>Schrankia microphylla</u>	Sensitive brier
<u>Sesbania exaltata</u>	Sesbania
<u>Setaria geniculata</u>	Foxtail
<u>Setaria glauca</u>	Foxtail
<u>Sida spinosa</u>	Prickly mallow
<u>Smilax bona-nox</u>	Greenbrier
<u>Smilax rotundifolia</u>	Common greenbrier
<u>Solanum carolinense</u>	Horse-nettle

(Continued)

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<u>Scientific Name</u>	<u>Common Name</u>
<u>Sorghum halepense</u>	Johnsongrass
<u>Spilanthes americana</u>	Spilanthes
<u>Sporobolus sp.</u>	Dropseed
<u>Strophostyles helvola</u>	Wildbean
<u>Teucrium canadense</u>	Germander
<u>Trachelospermum difforme</u>	Starjessamine
<u>Ulmus rubra</u>	Slippery elm
<u>Verbena urticifolia</u>	Verbena
<u>Vitis cinerea</u>	Pigeon grape
<u>Vitis riparia</u>	Riverbank grape
<u>Xanthium strumarum</u>	Cocklebur
<u>Zizaniopsis millacea</u>	Water millet

(Concluded)